

$Z^+(4430)$ as a resonance in the $D_1(D'_1)D^*$ channel

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We study the possibility that the $Z^+(4430)$ state observed by Belle is a D_1D^* (or D'_1D^*) resonance in S-wave. Focusing on its decays, We find that the open-charm decay into $D^*D^*\pi$ is dominant. Furthermore, we use the re-scattering mechanism to study its hidden-charm decays and find that the re-scattering effects are significant in D_1D^* channel but not in D'_1D^* channel. For the $J^P = 1^-$ candidate, with chosen parameters, we can get $\Gamma(Z^+ \rightarrow \psi'\pi^+)/\Gamma(Z^+ \rightarrow J/\psi\pi^+) \approx 5.3$, which tends to account for why the $Z^+(4430)$ is difficult to be found in $J/\psi\pi^+$. However, the 0^- candidate can not be ruled out by our calculations.

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I. INTRODUCTION

Recently, there have been a number of exciting discoveries of new hadron states in the hidden-charm sector. Among these new states, the $Z^\pm(4430)$ may be the most special one, which was discovered by the Belle collaboration [1] in the invariant mass spectrum of $\psi'\pi^\pm$ in the decay $B \rightarrow \psi'\pi^\pm K$ with mass $m_Z = 4433 \pm 4 \pm 1$ MeV and width $\Gamma_Z = 44^{+17+30}_{-13-11}$ MeV.

The distinguishable feature of $Z^\pm(4430)$ is that it is a charged resonance-like structure. Surely it can not be emplaced in ordinary charmonium sector or explained by couple channel effects between charmonium and open-charm thresholds. The closeness of m_Z to the thresholds of $D^*(2010)D_1(2420)$ and $D^*(2010)D'_1(2430)$ may suggest that it is induced by the threshold effects of these channels. However, it may not be a simple kinematic effect since it is very narrow and the line-shape of $\psi'\pi$ distribution is very sharp. Presumably, it is likely to be a resonance of D^*D_1 (or $D^*D'_1$). Here, a "resonance" means a state formed in the $D^*(2010)-D_1(2420)$ scattering by some inter-hadron forces (say, meson exchanges), but not the bound state formed by the colored-confining forces. Note that in the B^+ decays, the CKM favored modes such as $B^+ \rightarrow \bar{D}^*(2010)^0 D_s^{*+}$ has a very large branching ratio of about 2% [2]. This can happen not only for the D_s^{*+} but also for the excited D_s^{*+} system, which can decay into D^+K^0 and D^0K^+ as well as $D_1^+(2420)K^0$ and $D_1^0(2420)K^+$ with sizable branching ratios. Then in the scattering process of $\bar{D}^*(2010)^0 - D_1^+(2420)$ and $\bar{D}^*(2010)^0 - D_1^0(2420)$, resonance-like structures Z^+ and Z^0 may be formed.

Here, we will not try to clarify the complicated dynamics in the $D^*D_1^{(\prime)}$ scattering in this paper. However, it is worth emphasizing that the configuration of $D^*D_1^{(\prime)}$ in Z should favor S-wave because a centrifugal barrier will prevent the formation of a resonance state. Then, the allowed J^P of Z is 0^- , 1^- or 2^- . Thereinto, the possibility of 2^- may be neglected since its production in $B \rightarrow Z(4430)K$ decay is suppressed by the small phase space.

Another unusual feature about $Z(4430)$ is that there is no report [1] on $Z^+ \rightarrow J/\psi\pi^+$ in the $J/\psi \rightarrow l^+l^-$ mode, which implies the ratio

$$R_{\psi'/\psi} = \frac{\Gamma(Z^+ \rightarrow \psi'\pi^+)}{\Gamma(Z^+ \rightarrow J/\psi\pi^+)} \gg 1. \quad (1)$$

It is not easy to understand this "J/ψ-suppressed problem" since J/ψ has many properties similar to ψ' and the phase space should favor the J/ψ production.

In this paper, we will stress on the decays of Z assuming that it is a $D^*D_1^{(\prime)}$ resonance with $J^P = 0^-$ or 1^- . Since $D_1^{(\prime)}$ decays to $D^*\pi$ dominantly, one can expect the width of Z is dominated by $\Gamma(Z \rightarrow D^*D^*\pi)$. On the other hand, since Z is discovered in $\psi'\pi$ system with a quite large product branching ratio:

$$\mathcal{B}(B \rightarrow ZK) \times \mathcal{B}(Z \rightarrow \psi'\pi) = (4.1 \pm 1.0 \pm 1.3) \times 10^{-5}, \quad (2)$$

the partial width $\Gamma(Z \rightarrow \psi'\pi)$ should also be quite significant. Together with the "J/ψ-suppressed problem", this implies that the mechanism, which induces these hidden-charm decay modes, should have some nontrivial features. We will examine these modes in the re-scattering model [3, 4, 5, 6], in which the $D^*D_1^{(\prime)}$ component is re-scattered into $\psi^{(\prime)}\pi$ by one $D^{(*)}$ meson exchange. In this picture, the form factor suppression, which accounts for the off-shell effects of the intermediate meson, will favor ψ' because its mass is closer to the $D^{(*)}\bar{D}^{(*)}$ thresholds than that of J/ψ . We find that the larger width of $Z \rightarrow \psi'\pi$ and the J/ψ-suppressed problem may be explained if one choose adequate parameters.

Needless to say, as charged states, the Z^\pm should be in a isospin-triplet, and their isospin partner Z^0 should exist. In our analysis, we will focus on Z^+ . However, all the results can be applied to Z^0 directly if the interaction between Z and $D^*D_1^{(\prime)}$ has isospin symmetry.

We give the model to describe the decays of $Z^+(4430)$ in Sec. II. The numerical analysis and discussions are given in Sec. III. And a summary is given in Sec. IV.

II. THE DECAYS OF $Z^+(4430)$

As a charged resonance, the $Z^+(4430)$ can be coupled to either $\bar{D}^{*0}D_1^{(\prime)+}$ or $D^{*+}D_1^{(\prime)0}$. We will describe their interactions by the following effective Lagrangians with isospin symmetry:

$$\mathcal{L}_{ZD_1^0 D^*}^0 = g_{ZD_1^0 D^*}^0 Z(D^* \cdot D_1^{(\prime)\dagger}) + h.c. \quad \text{for } 0^-, (3)$$

$$\mathcal{L}_{ZD_1^0 D^*}^1 = ig_{ZD_1^0 D^*}^1 \epsilon^{\mu\nu\rho\sigma} D_\mu^* D_{1\nu}^{(\prime)\dagger} \partial_\rho Z_\sigma + h.c. \quad \text{for } 1^-, (4)$$

where the coupling constants $g_{ZD_1^0 D^*}^{0,1}$ are blind to the charge of D meson, but there can be significant difference between these for D_1 and for D_1' due to the dynamics in $D^*D_1^{(\prime)}$ systems. As we have mentioned in Sec. I, we only introduce S-wave coupling between Z and $D^*D_1^{(\prime)}$ with $J^P(Z) = 0^-$ and 1^- in Eq. (3) and (4), respectively. Then, the study on the decays of Z resonance is exigent to clarify its quantum number even its components.

In this section, we will focus on two primary decay modes of Z , i.e., the open-charm mode $Z \rightarrow D^*D^*\pi$ and the hidden-charm mode $Z \rightarrow J/\psi(\psi')\pi$. For the open-charm mode, we assume that one of the two D^* s arise from the decay of $D_1(D_1')$ component and the propagation of virtual $D_1(D_1')$ is described by the Breit-Wigner propagator. For the hidden-charm decay mode, we use re-scattering mechanism, which was used in the analysis of $X(3872) \rightarrow J/\psi\rho$ [6].

A. $Z^+ \rightarrow \psi^{(\prime)}\pi^+$

In the re-scattering mechanism, the decay $Z^+ \rightarrow J/\psi(\psi')\pi^+$ can arise from exchange of a $D^{(*)}$ meson between D^* and $D_1(D_1')$. We will not take into account higher excited D meson medium states because their contributions will be suppressed by the form factors intensively. The Feynman diagrams for $Z^+(4430) \rightarrow \bar{D}^{*0}D_1^+(D^{*+}D_1^0) \rightarrow J/\psi(\psi')\pi^+$ are shown in Fig. 1. The diagrams for D^*D_1' re-scattering are the same.

To evaluate the amplitudes, we need the following effective [7, 8] Lagrangians:

$$\begin{aligned} \mathcal{L}_{\psi D^* D^*} &= -ig_{\psi D^* D^*} \left\{ \psi^\mu (\partial_\mu D^{*\nu} D_\nu^{*\dagger} - D^{*\nu} \partial_\mu D_\nu^{*\dagger}) \right. \\ &\quad \left. + \psi^\nu D^{*\mu} \partial_\mu D_\nu^{*\dagger} - \psi_\nu \partial_\mu D^{*\mu} D_\nu^{*\dagger} \right\}, \end{aligned} \quad (5)$$

$$\mathcal{L}_{\psi D_1^0 D} = g_{\psi D_1^0 D} (\psi \cdot D_1^{(\prime)}) D^\dagger + h.c., \quad (6)$$

$$\begin{aligned} \mathcal{L}_{D_1 D^* \pi} &= ig_{D_1 D^* \pi} [-3D_\mu^* D_{1\nu}^\dagger \partial^\mu \partial^\nu \pi + (D^* \cdot D_1^\dagger) \partial^2 \pi \\ &\quad - \frac{1}{m_{D^*} m_{D_1}} \partial_\mu D^{*\rho} \partial_\nu D_{1\rho}^\dagger \partial^\mu \partial^\nu \pi] + h.c., \end{aligned} \quad (7)$$

$$\mathcal{L}_{D_1' D^* \pi} = ig_{D_1' D^* \pi} D^{*\mu} \partial_\nu D_{1'\mu}^\dagger \partial^\nu \pi + h.c., \quad (8)$$

$$\mathcal{L}_{D^* D \pi} = ig_{D^* D \pi} D_\mu^* \partial^\mu \pi D^\dagger + h.c.. \quad (9)$$

Again, we assume that the isospin symmetry is preserved in (5)-(9). That is, the coupling constants are blind to the

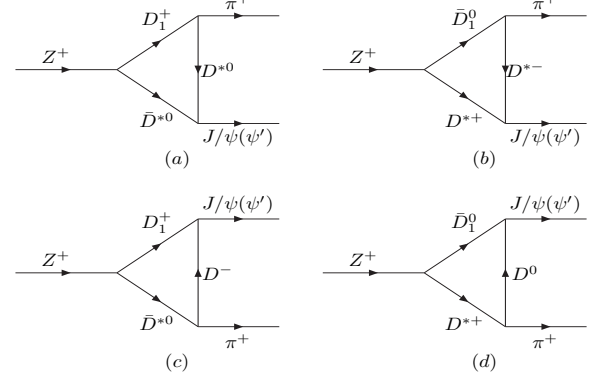


FIG. 1: The decay diagrams for $Z^+(4430) \rightarrow \bar{D}^{*0}D_1^+(D^{*+}D_1^0) \rightarrow J/\psi(\psi')\pi^+$.

flavor of light quarks and the coupling constants in (7)-(9) should product by a factor of $1/\sqrt{2}$ for interactions involving π^0 .

For convenience, we define the following ratios:

$$r_{D^* D^*} = \frac{g_{\psi' D^* D^*}}{g_{\psi D^* D^*}}, \quad r_{D_1^0 D} = \frac{g_{\psi D_1^0 D}}{g_{\psi D_1^0 D}}. \quad (10)$$

In our analysis in Sec. III, we will not distinguish them seriously, but call them as "r" totally.

All the coupling constants will be determined in the next section. However, it is necessary to emphasize here that the determinations will not account for the off-shell effect of the exchanged $D(D^*)$ meson, of which the virtuality can not be ignored. Such effects can be accounted for by introducing, e.g., the monopole [3] or dipole [4] form factors for off-shell vertexes. Let q denote the momentum transferred and m_i the mass of exchanged meson, the form factor can be written as

$$\mathcal{F}(m_i, q^2) = \left(\frac{\Lambda^2 - m_i^2}{\Lambda^2 - q^2} \right)^n, \quad (11)$$

and the cutoff Λ can be parameterized as

$$\Lambda(m_i) = m_i + \alpha \Lambda_{QCD}. \quad (12)$$

As we have mentioned, this form factor may play a important role in understanding the "J/ψ-suppressed problem". So our numerical results will be very sensitive to the values of n and α . Since increasing of n is equivalent to decreasing of α in a large kinematical region, we will choose to fix $\alpha = 3$, and to vary the value of n from 1 to 2.

We are now in a position to compute the diagrams in Fig. 1. If the $Z^+(4430)$ lies above the $D^*D_1(D^*D_1')$ threshold, in the processes $Z(p_X, \epsilon_X) \rightarrow D_1(D_1')(p_1, \epsilon_1) + D^*(p_2, \epsilon_2) \rightarrow \psi(\psi')(p_3, \epsilon_3) + \pi(p_4)$, where the momenta p and polarization vectors ϵ are denoted explicitly for the

mesons, we can calculate the absorptive part (imaginary part) of Fig. 1 and find it to be given by

$$\begin{aligned} \text{Abs}_i &= \frac{|\vec{p}_2|}{32\pi^2 m_Z} \int d\Omega \mathcal{A}_i(Z \rightarrow D^* \bar{D}_1(D'_1)) \\ &\times \mathcal{A}_i(D^* \bar{D}_1(D'_1) \rightarrow \psi(\psi')\pi), \end{aligned} \quad (13)$$

where $i = (a, b, c, d)$ and \vec{p}_2 is the 3-momentum of the on-shell D^* meson in the rest frame of $Z(4430)$.

Neglecting the mass difference between charged and neutral D mesons, the amplitudes of Fig. 1(a) and 1(c) will be equal to those of Fig. 1(b) and 1(d), respectively. However, the absorptive part of the amplitude is indeed sensitive to the difference between the threshold of $\bar{D}^{*0}D_1^{(\prime)+}$ and of $D^{*+}D_1^{(\prime)0}$. This is because the absorptive part in (13) is proportional to the phase space factor $|\vec{p}_2|/m_2$ and is sensitive to the exact position of the threshold. On the other hand, the absorptive part is strongly suppressed by this phase space factor. Even smeared with the Breit-Wigner distribution function

$$\frac{1}{\pi} \frac{\sqrt{t}\Gamma_i(t)}{(t - m_i^2)^2 + t\Gamma_i(t)^2}, \quad i = D_1, D'_1, \quad (14)$$

the absorptive part is still less than the real part of the amplitude and can be neglected.

The evaluation of the real part of the amplitude is difficult to be achieved. We will follow Ref. [6] to obtain it from absorptive part via the dispersion relation:

$$\text{Dis}(m_Z^2) = \sum_{i=a}^d \frac{1}{\pi} \int_{th^2}^{\infty} \frac{\text{Abs}_i(s')}{s' - m_Z^2} ds', \quad (15)$$

where $th = m_1 + m_2$ is the threshold. To proceed, we need a reasonable cutoff for the integral in (15). We choose to add a form factor on the absorptive part [9, 10]:

$$\text{Abs}_i(s) \rightarrow \text{Abs}_i(s) e^{-\beta |\vec{p}_2|^2}, \quad (16)$$

where the cutoff β can be related with the effective radius of interaction R by $\beta = R^2/6$. The authors of Ref. [9] choose $\beta = 0.4 \text{ GeV}^{-2}$, which corresponds to $R \approx 0.3 \text{ fm}$. We will choose $\beta = 0.4\text{--}1.0 \text{ GeV}^{-2}$ for our numerical analysis.

B. $Z \rightarrow D^* D^* \pi$

For the cascade decay $Z \rightarrow D^* D_1(D'_1) \rightarrow D^* D^* \pi$, the Feynman diagrams four Z^+ decay modes are illustrated in Fig. 2. The four diagrams in Fig. 2 are related by the isospin symmetry, and one can easily obtain the approximate relation:

$$\begin{aligned} \Gamma(Z^+ \rightarrow D^{*+} D^{*-} \pi^+) &\approx \Gamma(Z^+ \rightarrow \bar{D}^{*0} D^{*0} \pi^+) \\ &\approx \frac{1}{2} \Gamma(Z^+ \rightarrow \bar{D}^{*0} D^{*+} \pi^0). \end{aligned}$$

Since in our model, one D^* directly comes from the virtual $D_1(D'_1)$ component and have no interference with

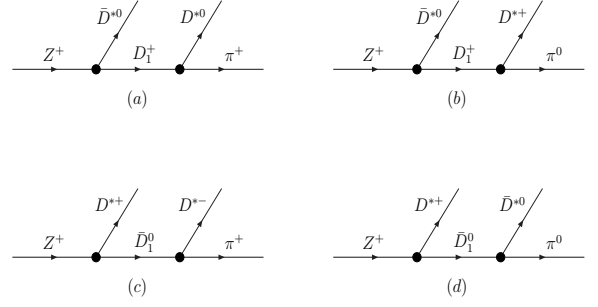


FIG. 2: The diagrams for $Z^+(4430) \rightarrow D^* D^* \pi^+$.

the other D^* , we can use the formula for cascade decay to evaluate the partial width as

$$\begin{aligned} \Gamma_{Z^+ \rightarrow D^{*+} D^{*-} \pi^+} &= \frac{1}{\pi} \int_{(m_\pi + m_{D^*})^2}^{(m_Z - m_{D^*})^2} ds \sqrt{s} \\ &\times \frac{\Gamma_{Z^+ \rightarrow D^{*+} \bar{D}_1^{(\prime)0} \pi^+}(s) \Gamma_{\bar{D}_1^{(\prime)0} \rightarrow D^{*-} \pi^+}(s)}{(s - m_{D_1^{(\prime)}}^2)^2 + (\sqrt{s} \Gamma_{D_1^{(\prime)}})^2}. \end{aligned} \quad (17)$$

For the neutral state Z^0 , the number of the diagrams for decay $Z^0 \rightarrow D^* D^* \pi$ is eight. However, the total width of open-charm decay of Z^0 should be approximation equal to that of Z^+ in our model.

III. NUMERICAL RESULTS AND DISCUSSIONS

The coupling constants of $DD\pi$ in (7)-(9) can be related to the well-known parameters in Heavy Meson Chiral Lagrangian through the relations [7, 8]:

$$\begin{aligned} g_{D^* D \pi} &= 2 \frac{g}{f_\pi} \sqrt{m_{D^*} m_D}, \quad g_{D_1^* D^* \pi} = 2 \frac{h}{f_\pi} \sqrt{m_{D^*} m_{D_1^*}}, \\ g_{D_1^* D^* \pi} &= \frac{2}{\sqrt{6}} \frac{h_1 + h_2}{f_\pi \Lambda_\chi} \sqrt{m_{D^*} m_{D_1^*}}, \end{aligned} \quad (18)$$

where f_π is the decay constant of π and Λ_χ is chiral symmetry breaking scale. The parameters in (18) can be roughly estimated through the measurement of the width of $D^{*+}(D'_1, D_1)$ [2]. Using the central value of these widths, the parameters $|h_1 + h_2|$, h and g can be evaluated and we list them in Tab. I.

The evaluations of the coupling constants $g_{\psi D^* D^*}$ and $g_{\psi D_1^{(\prime)} D}$ are somewhat difficult since there are hardly any experimental data to be used. The two things we can use are symmetry and model. For $g_{\psi D^* D^*}$, we can relate it to $g_{\psi DD}$ through heavy quark symmetry, and then estimate its value with the help of Vector Meson Dominant (VMD) model [11]:

$$g_{\psi D^* D^*} \approx g_{\psi DD} \approx \frac{m_\psi}{f_\psi} \approx 8, \quad (19)$$

TABLE I: Parameters used in the calculations.

$g_{\psi D^* D^*}$	$g_{\psi D_1^{(0)} D^*}$	$ h_1 + h_2 /\Lambda_\chi$	h	g
8	5 GeV	1 GeV ⁻¹	0.7	0.6
$g_{Z D_1^{(0)} D}^0$	$g_{Z D_1^{(0)} D^*}^1$	f_π	Λ_{QCD}	r
5 GeV	1.5	132 MeV	220 MeV	2

where f_ψ is the decay constant of ψ . For $g_{\psi D_1(D_1') D}$, we take it as large as $g_{\psi(4415) D_1 D}$, which can be estimated through the prediction of $\Gamma(\psi(4415) \rightarrow D_1 D)$ in 3P_0 model [12].

The coupling constant $g_{Z D_1 D^*}^1$ and the re-scaled one $g_{Z D_1' D^*}^0/\sqrt{m_Z m_{D^*}}$ should be smaller than $g_{\psi D^* D^*}$ since as a resonance in $D_1^{(0)} D^*$, Z must couples with $D_1^{(0)} D^*$ through some weak dynamics (say, π -exchange). So we choose

$$g_{Z D_1^{(0)} D^*}^1 = 1.5, \quad g_{Z D_1^{(0)} D^*}^0 = 5 \text{ GeV}$$

in Tab. I. And these parameters give the prediction on partial widths of open-charm decays of $Z(4430)$:

$$\begin{aligned} \Gamma(Z(0^-) \rightarrow D_1 D^* \rightarrow D^* D^* \pi) &= 25 \text{ MeV}, \\ \Gamma(Z(0^-) \rightarrow D_1' D^* \rightarrow D^* D^* \pi) &= 37 \text{ MeV}, \\ \Gamma(Z(1^-) \rightarrow D_1 D^* \rightarrow D^* D^* \pi) &= 32 \text{ MeV}, \\ \Gamma(Z(1^-) \rightarrow D_1' D^* \rightarrow D^* D^* \pi) &= 46 \text{ MeV}. \end{aligned} \quad (20)$$

On the other hand, we also consider about that the resonance decays to $D_1^{(0)} D^*$ directly. After smeared with the Breit-Wigner distribution functions defined in (14), all the partial widths is about 30 GeV. So, we will use the numbers in (20) in our discussions.

As for the hidden-charm decay $Z^+ \rightarrow \psi' \pi^+$, the width is squarely dependent on the value of r , which is defined in (10). It have been argued that the coupling between DD system and excited charmonium is generally not weak comparing with that for J/ψ . For example, the experimental data tell us that the coupling constant $g_{\psi(3770) DD} \approx 24$, which is about 3 times of $g_{\psi DD}$. That is, the value of r tends to be greater than 1. In our discussion, we choose relative large value for r in Tab. I to examine the possibilities to understand the " J/ψ -suppression problem" in our model.

Evaluating the amplitudes in (15) numerically, we find that the contributions from $D^* D_1'$ channel are far less than those from $D^* D_1$ channel. This is mainly because the large width of D_1' reduces the threshold effects consumedly. On the other hand, the contributions arising from Fig. 1(c)-1(d) are less than those from Fig. 1(a)-1(b) by a factor of 15-30. This is probably because the value coupling constant $g_{\psi D_1 D}$ which we choose in Tab. I is small. We can see it through re-scaling $g_{\psi D_1 D}$ by $\sqrt{m_{D_1} m_D}$ and getting the number is 2.3, which is far less than that of $g_{\psi D^* D^*}$.

The numerical result of the partial widths $\Gamma(Z^+) \rightarrow \psi^{(\prime)} \pi^+$ are listed in Tab. II. Here, the contributions involved are only that arising from Fig. 1(a)-1(b) in $D^* D_1$

TABLE II: The predictions of $\Gamma(Z^+) \rightarrow \psi^{(\prime)} \pi^+$ and their dependence on (n, β) . Here, we only involve the contributions arising from Fig. 1(a)-1(b) in $D^* D_1$ channel.

$(n, \beta \times \text{GeV}^2)$	(1.0, 1.0)		(1.5, 0.6)		(2.0, 0.4)	
$J^P(Z)$	0 ⁻	1 ⁻	0 ⁻	1 ⁻	0 ⁻	1 ⁻
$\Gamma_{\psi\pi^+}(\text{MeV})$	2.4	4.7	0.68	1.4	0.19	0.36
$\Gamma_{\psi'\pi^+}(\text{MeV})$	1.6	6.0	1.1	3.8	0.64	1.9

channel. From Tab. II, one can find that the prediction on $R_{\psi'/\psi}$ increases with the parameter n increasing as one expects. For the 0⁻ candidate, the ratio $R_{\psi'/\psi} \approx 3$ at $n = 2$, which have implied the " J/ψ suppression" in some degree. However, the prediction on the partial width at $n = 2$ is too small comparing with the open-charm one in (20), which indicates that: $\mathcal{B}(Z^+(0^-) \rightarrow \psi' \pi^+) \sim 2.5\%$ and $\mathcal{B}(B \rightarrow ZK) \sim 1.6 \times 10^{-3}\%$. So the experimental data seems to disfavor the 0⁻ candidate.

For the 1⁻ candidate, when $n = 2$, the prediction on the ratio $R_{\psi'/\psi} \approx 5$ with $\mathcal{B}(Z^+(0^-) \rightarrow \psi' \pi^+) \sim 6\%$, which are better than that of 0⁻ candidate and are roughly consistent with experimental data.

If we choose $\alpha < 3$ [10] and fix $n = 2$, it is easy to get a large value prediction on $R_{\psi'/\psi}$ which can be consistent with the experimental constraint in (1). As a price to pay, the prediction of $\Gamma_{\psi' \pi^+}$ will be decreased. On the other hand, if the coupling constant $g_{\psi D_1 D}$ is not as small as that given in Tab. I, or if we can evaluate it by re-scaling $g_{\psi D^{(*)} D^{(*)}} \sqrt{m_{D_1} m_D}$, then the contributions arising from Fig. 1(c)-1(d) will be comparable to those from Fig. 1(a)-1(b), and the width $\Gamma_{\psi' \pi^+}$ might be enhanced significantly since the interference effects turn to be important. Moreover, in Fig. 1(c)-1(d), the couplings of $\psi^{(\prime)} DD$ are S-wave while those in Fig. 1(a)-1(b) are P-wave. So, the configurations in Fig. 1(c)-1(d) are more in favor of ψ' -productions than those in Fig. 1(a)-1(b).

In conclusion, our calculations imply that the $Z^+(4430)$ state is likely to be a resonance in S-wave $D^* D_1$ scattering, and the spin-parity favors 1⁻ but can not rule out 0⁻. Further studies on its production mechanism are needed.

IV. SUMMARY

In summary, we study both the open-charm and the hidden-charm decays of $Z(4430)$ based on the assumptions that it is a $D_1^{(0)} D^*$ resonance in S-wave. The partial width of open-charm decay is dominant and can be adjusted to be 30-40 MeV. Then, we find that the S-wave threshold effects are significant in $D_1 D^*$ channel and are suppressed intensively in $D_1' D^*$ channel due to the larger width of D_1' . For the 1⁻ candidate, choosing parameters aptly, we can get $\Gamma(Z^+ \rightarrow \psi' \pi^+) \approx 2 \text{ MeV}$ with $R_{\psi'/\psi} \approx 5.3$, which could be roughly consistent with experimental data. But the 0⁻ candidate can not be ruled out by our calculations. Further studies on the produc-

tion mechanism of $Z(4430)$ are needed.

Note. When this manuscript was written, two papers about the $Z^+(4430)$ appeared. In [13], a similar idea to ours was proposed; while in [14] a tetraquark explanation was suggested.

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